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GEA-1094
Old Series Y-2129

INTERIOR ILLUMINATION

By

H. E. Mahan

ILLUMINATING ENGINEERING LABORATORY

General Electric Co.

Schenectady, N. Y.

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The following data is offered as a brief summary of a few of the fundamental considerations underlying the design of interior lighting systems in order that salesmen not specializing on lighting equipment may have some familiarity with illumination and thus more efficiently serve the customer and the General Electric Company. Our consideration of the subject in this pamphlet must of necessity be very superficial.

AVOID GLARE

Glaring light sources are responsible for the failure of many lighting systems. Glare causes eye strain and fatigue, interferes with vision and increases the accident hazard. Glare may be caused by exposed light sources or contrasts in surface brightness. These may be avoided by properly shading the lamps and distributing the light uniformly within the field of view.

DISTRIBUTION OF LIGHT

The degree to which shadows are minimized is dependent upon the distribution of light. A diffused light softens shadows because it comes from many directions; a unidirectional light creates dark, sharp shadows. Each system has its field of application, a well diffused light best fulfilling the conditions of the workshop or office and a strongly directional light being required at times to give proper form to architectural features.

QUALITY OF LIGHT

The spectral composition of artificial light is important in many industries and for many purposes, as for example, where objects viewed under artificial light are to appear as they do under daylight. Inasmuch as the color of objects is dependent upon the quality of light incident upon them, it is necessary to give consideration to this question in operations requiring color discrimination.

INTENSITY

The intensity of illumination required is dependent upon the character of work or nature of the building. Sufficient intensity should be provided to enable the eye to function properly and to comfortably do that which is required of it. A study of conditions should, therefore, be made to determine what will constitute adequate illumination for the conditions at hand.

We show in Table No. 1 a guide to illumination intensities. For further details see the Transactions of the Illuminating Engineering Society, State Codes, etc.

SPACING AND MOUNTING HEIGHT

The spacing and mounting height of luminaires are usually determined by the structural features of the building. It is essential to give these matters serious consideration if the distribution of light is to be satisfactory and objectionable glare is to be avoided. The curve shown on H-79039 gives approximately correct values for spacing and mounting heights for uniform illumination on a working plane 30 in. above the floor.

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ILLUMINATION CALCULATION

There are two methods commonly used in calculating illumination known as the "lumen method" and the "power method". The symbols used in the formulae for these two methods are these:

L = lumens required per outlet (By referring to table No. 2 the size of lamp may be obtained. It is advisable to use the nearest largest size lamp).

A = area to be lighted

F = foot-candles required (see table No. 1)

N = number of outlets

K = Coef. of utilization (see table No. 3)

This constant also includes a depreciation of 25% to compensate for normal dust and dirt accumulation on lamps and reflector equipment.

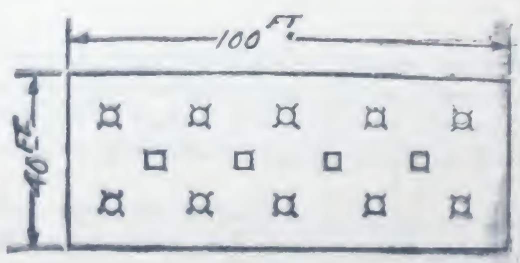
W = watts per square foot required per foot-candle
(see H-79724 and H-79725)

P = watts per outlet or size of lamp

THE LUMEN METHOD

$$L = \frac{A \times F}{N \times K}$$

for example, assume a factory floor 40 ft. by 100 ft. or 4000 sq. ft. in area,



ceiling height 18 ft, bays 20 ft. by 20 ft. so that one outlet per bay is permissible. (See curve H-79039)

Space is to be used as a machine shop (fine work) requiring 12 foot-candles. The RLM standard dome and bowl enameled MAZDA lamp selected for the unit. Walls and ceiling medium tone K (see table No. 3) therefore is .40.

$$L = \frac{4000 \times 12}{10 \times .40} \quad \text{(see formula referred to above)}$$

$$= 12000 \text{ lumens}$$

Referring to table No. 2 we find nearest standard size MAZDA lamp to 12000 lumens is 750 watts (14500 lumens).

THE POWER METHOD

The power method is based on the power required to produce one foot-candle of illumination, thus:

$$P = \frac{W \times F \times A}{N}$$

Assume the problem referred to above

$$P = \frac{.15 \times 12 \times 4000}{10}$$

$$= 720 \text{ watts—nearest standard size 750 watt lamp}$$

SYSTEMS OF LIGHTING

Systems of lighting have been classified in accordance with the characteristics of light distribution. These systems are known as direct, indirect, semi-indirect and diffusing and have the essential characteristics shown by the chart C-46683.

DIRECT LIGHTING

This system delivers the light directly to the working plane and is, therefore, the most efficient system in terms of actual light delivered per unit of power. Care must be exercised with this system of lighting to avoid objectionable glare. Shadows and lack of diffusion are also likely to result from this method of lighting unless properly designed. Bowl enameled lamps are preferable to clear lamps in equipment of this type in order to obscure the lamp filament from view. This method of lighting is confined largely to factory buildings.

INDIRECT LIGHTING

In this system of lighting the light is directed to the ceiling from which it is diffused to the useful plane. This method of lighting shows the least efficiency in terms of effective lumens per watt but gives the maximum of diffusion and eye protection.

SEMI-INDIRECT LIGHTING

This system embodies the principles of the direct and indirect lighting; part of the light is directed to the ceiling and diffused throughout the room and part delivered directly to the useful plane. By choosing the proper density of glassware the desired proportions of these two components may be obtained for any desired effect. The lumens per watt efficiency is proportional to the relative proportions of the above components as is also the diffusion and degree of eye protection. The system is capable of a wide range of variation and is the most widely used method of lighting buildings other than factory space.

DIFFUSED LIGHTING

In this system of lighting the lamp is entirely enclosed within a diffusing glass envelope. The distribution of light is practically independent of the shape of the globe and gives very satisfactory illumination. The efficiency, eye protection, etc. depend upon the density of the glassware.

The charts shown in Figs. H-79725 and H-79724 have been prepared to indicate the characteristics of typical industrial and general interior luminaires. The essential data are given on these charts to enable one to determine the equipment required for any desired intensity of illumination.

% TOTAL LUMENS OF LAMP

This expresses the percentage of the total lumens generated by the lamp as given in the table of lamp lumens which are delivered by the luminaire; thus,

Efficiency of the R.L.M. standard reflector is 68%

Total lumens of 300 watt bowl enameled MAZDA lamp (See Fig. H-79725) 4500

Therefore, the total lumens delivered by the standard R. L. M. reflector and 300 watt bowl enameled lamp are 68% of 4500 or 3060 lumens.

% UPWARD LUMENS

This expresses the percentage of the lumens delivered by the luminaire which are emitted above the horizontal. This light becomes effective on the working plane only after reflection from ceiling and walls. The upward lumens multiplied by the coefficient of reflection of the reflecting surface (ceiling or walls) is a close approximation of the quantity of light reaching the working plane, Thus,

Lumens of 300 watt clear MAZDA lamp (see table)	4900
Efficiency of Trojan luminaire (see chart H-79724)	83%
Total lumens delivered by the Trojan luminaire	4067
% upward lumens (see chart H-79724)	45%
Total upward lumens (.45 x 4067)	1830
White ceiling (see table of reflection coefficients Edison Bulletin LD-102-A)	80%
Upward lumens effective on working plane (.80 x 1830)	1464

Upward light is also useful in many types of industrial buildings to eliminate the gloomy appearance of a sharp cutoff and dark ceilings.

% DOWNWARD LUMENS

This expresses the percentage of the lumens delivered by the luminaire which are emitted below the horizontal. This light in general is assumed to be effective on the working plane without additional losses due to reflection. Thus,

Total lumens of 300 watt clear lamp (see chart H-79724)	4900
Efficiency of Ivanhoe Ace luminaire (see chart H-79724)	70%
Total lumens from luminaire (70% of 4900)	3430
% Downward lumens (see chart H-79724)	63%
Downward lumens (.63 x 3430)	2161

These data referring to lighting are very general and necessarily incomplete. The subject deserves careful consideration and expert counsel and in this connection we offer to architects and engineers the services of our engineers specializing in illuminating problems.

APPENDIX

Table No. 1

	Foot-Candles		
Auditoriums, Churches	2	–	4
Armories	3	–	5
Exhibition Halls	4	–	6
Schools, Class-rooms, study rooms, libraries	4	–	8
Stores:			
Show Windows	10	–	70
First floor of Department Store, Shop on bright street or corner	7	–	10
Other floors of Department Store, Clothing, Drygoods, Haberdashery, Millinery, Jewelry, etc.	5	–	8
Offices:			
Private General	6	–	10
Drafting Room	10	–	15
Industrial:			
Yards	.25	–	.5
Stairways, Passageways and Corridors	1	–	2
Rough Manufacturing on large material such as Foundry; Pottery, Rough Wood Work, Rough Assembling, Forge Shop and Boiler Rooms, etc.	3	–	6
Medium Rough Manufacturing, such as Rough Machining, Rough Bench Work, Launderies, etc.	5	–	10
Fine Manufacturing, such as Fine Machining, Machine Wood Work, Pattern and Tool Making, Textilse, Press Rooms, Tobacco, Manufacturing, etc.	8	–	16

The higher values are advisable where the work being done is on dark goods or surfaces.

TABLE NO. 2

Lamp Data—Oct. 1, 1922

MAZDA C LAMPS—110 to 125 Volts

Watts	50	75	100	150	200	300	400	500	750	1000
Initial Lumens	500	880	1300	2100	3000	4900		9000	14500	20000

220 to 250 Volts

Watts	100	200	300	500	750	1000
Total Lumens	980	2500	4300	7800	12500	18000

DAYLIGHT MAZDA LAMPS—110 to 125 Volts

Watts	75	100	150	200	300	500
Total Lumens	600	900	1400	2100	3400	6100

Bowl enamel lamps approximately 8% less than clear lamps in initial lumens.

TABLE NO. 3

UTILIZATION CONSTANTS—PER CENT LUMENS EFFECTIVE

Allowing for Service Depreciation

Ceiling		Light			Medium			Dark	
Walls		Lt.	Med.	Dark	Lt.	Med.	Dark	Med.	Dark
Reflector	Mazda C Lamp								
RLM Standard Dome	Clear	.49	.47	.45	.48	.46	.44	.45	.44
RLM Standard Dome	Bowl Enam.	.42	.41	.39	.41	.40	.38	.39	.38
Deep Bowl, Steel	Clear*	.41	.39	.37	.39	.38	.37	.38	.37
Reflector Cap Diffuser	Clear	.35	.34	.32	.34	.33	.31	.32	.31
Deep Bowl, Glass	Bowl Enam.	.40	.38	.36	.37	.35	.33	.32	.31
Diffusing Enclosing Globe	Clear	.37	.34	.32	.35	.33	.31	.31	.30
Light Opal, Semi-Indirect	Clear	.34	.31	.28	.29	.26	.23	.21	.19
Dense Opal, Semi-Indirect	Clear	.29	.27	.25	.22	.20	.19	.16	.14
Totally Indirect	Clear	.27	.25	.23	.20	.18	.16	.12	.10

* Bowl Enameled Lamp, not generally recommended with the deep bowl opaque reflectors on account of the pocketing of light and resultant low utilization.

[illegible]

[illegible]

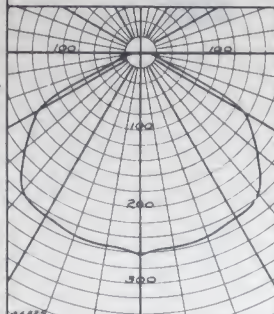
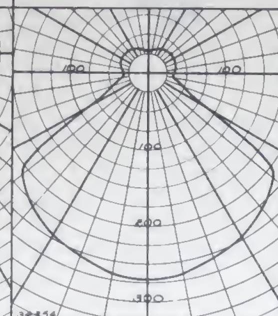
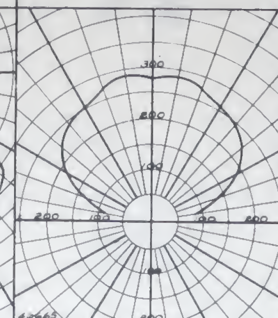
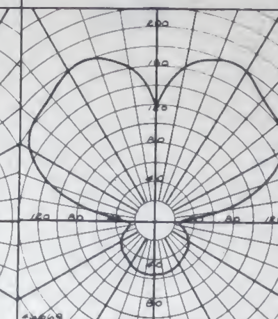
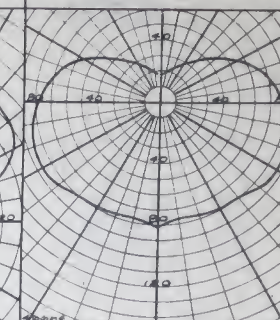
[illegible]

[illegible]

[illegible]

[illegible]

CHARACTERISTICS OF LIGHTING SYSTEMS

	DIRECT LIGHTING		INDIRECT LIGHTING	SEMI.-INDIRECT LIGHTING	DIFFUSED LIGHTING
	OPAQUE	TRANSLUCENT			
TYPICAL DISTRIBUTION CURVES					
LUMENS BARE LAMP	100%	100%	100%	100%	100%
% LUMENS DELIVERED BY LUMINAIRE	64	82	82	83	67
% UPWARD LUMENS	0	22	100	77	39
% DOWNWARD LUMENS	100	78	0	23	61
RELATIVE WATTAGE REQUIRED FOR EQUAL HORIZONTAL ILLUMINATION (APPROX)	1.15	1.00	1.50	1.30	1.30

TEST Nº 3378
CHECKED BY H.E.M.
INSPECTED BY A.L.E.P.

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ILLUMINATING ENG. LABORATORY
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SCHENECTADY, N.Y.

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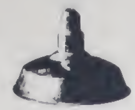
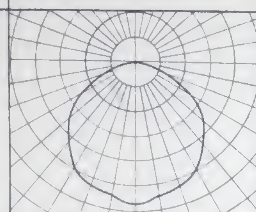
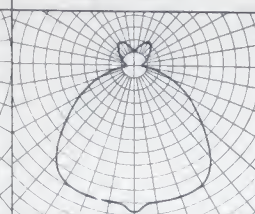
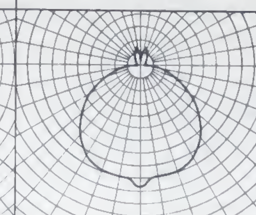
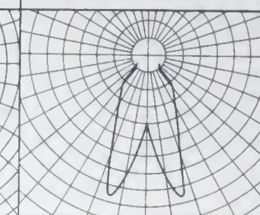
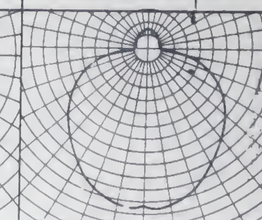
INDUSTRIAL LIGHTING EQUIPMENT

UNIT					
EQUIPMENT	R.L.M. STANDARD" DOME BOWL-ENAMELED MAZDA LAMP. 75-1000 WATTS	GLASS TOP DOME BOWL-ENAMELED MAZDA LAMP. 75-200 WATTS	GLASSTEEL DIFFUSER CLEAR MAZDA LAMP 75-300 WATTS	FORM 15 NOVALUX CLEAR MAZDA LAMP 300-500 WATTS	IVANHOE GLASS REFLECTOR" BOWL-ENAMELED MAZDA LAMP 25-200 WATTS
DISTRIBUTION CHARACTERISTIC					
% TOTAL LUMENS OF LAMP	68	70	67	69	80
% UPWARD LUMENS	0	19	10	0	14
% DOWNWARD LUMENS	100	81	90	100	86
% 0°-60° LUMENS	81	65	68	69	59
WATTS PER SQUARE FOOT PER FOOT-CANDLE	0.15	0.19	0.17	0.15	0.16

THE VALUES GIVEN FOR AVERAGE WATTS PER SQUARE FOOT OF FLOOR AREA REQUIRED PER FOOT-CANDLE OF ILLUMINATION ASSUME A SERVICE DEPRECIATION FACTOR OF 30%

LAMP LUMENS		
SIZE OF LAMP	BOWL-ENAMELED	CLEAR
75	828	900
100	1195	1300
150	1930	2100
200	2760	3000
300	4500	4900
500	8280	9000
750	13340	14500
1000	18400	20000

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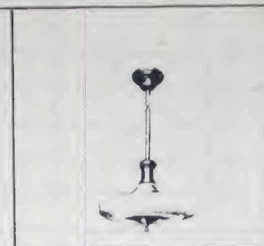
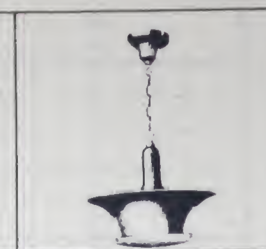
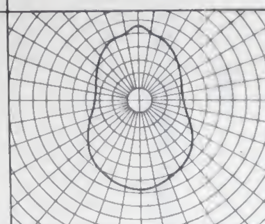
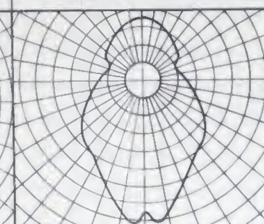
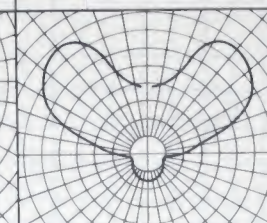
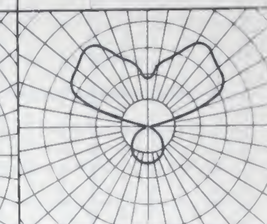
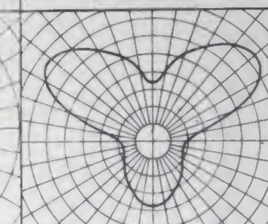
H-79725

LUMINAIRES FOR GENERAL ILLUMINATION

FIXTURE					
EQUIPMENT	IVANHOE TROJAN UNIT WITH CLEAR MAZDA LAMP. 75-500 WATTS	IVANHOE ACE UNIT WITH CLEAR MAZDA LAMP 100-500 WATTS	IVANHOE KELDON UNIT WITH CLEAR MAZDA LAMP 100-500 WATTS	DUPLEXALITE UNIT WITH CLEAR MAZDA LAMP 75-500 WATTS	FILTERLITE UNIT WITH CLEAR MAZDA LAMP 100-300 WATTS
DISTRIBUTION CHARACTERISTIC					
OVERALL EFFICIENCY OR % OF BARE LAMP LUMENS	83	70	67	75	79
% UPWARD LUMENS	45	37	84	80	70
% DOWNWARD LUMENS	55	63	16	20	30
APPROXIMATE WATTAGE PER SQUARE FOOT PER FOOT-CANDLE	0.15	0.17	0.24	0.21	0.23

THE VALUES GIVEN FOR AVERAGE WATTS PER SQUARE FOOT OF FLOOR AREA REQUIRED PER FOOT-CANDLE OF ILLUMINATION ASSUME THE CEILING AND WALLS ABOVE WAINSCOTTING FINISHED A FLAT WHITE OR CREAM TINT OF APPROXIMATELY 70% COEFFICIENT OF REFLECTION VALUES ALSO INCLUDE SERVICE DEPRECIATION FACTOR OF 30%.

LAMP LUMENS		
SIZE OF LAMP	BOWL ENAMELED	CLEAR
75	828	900
100	1195	1300
150	1930	2100
200	2760	3000
300	4500	4900
500	8280	9000
750	13340	14500
1000	18400	20000

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DEC 6 1922

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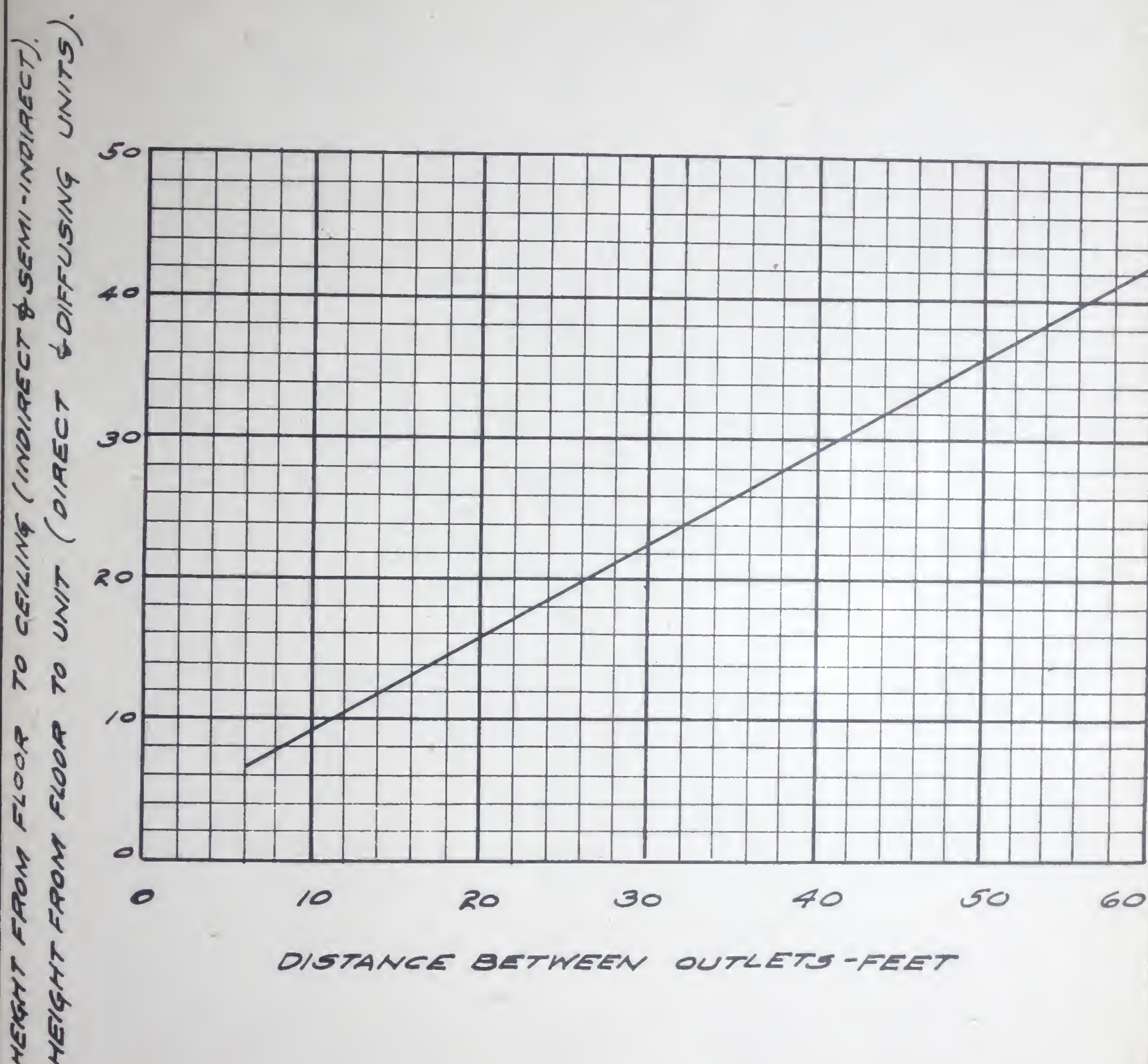
GENERAL ELECTRIC CO.
SCHENECTADY, N.Y.
H-79724

SPACING & MOUNTING HEIGHTS
FOR
LIGHTING UNITS



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CHECKED BY
INSPECTED BY S.L.E.R. (B)

5 JULY 29-1921 REVISED & RETRACED 7/28/22

H-79039